

HURRICANE SURVEY OF PAWCATUCK, CONN.

LETTER FROM THE SECRETARY OF THE ARMY TRANSMITTING

A LETTER FROM THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY, DATED JUNE 29, 1959, SUBMITTING A REPORT, TOGETHER WITH ACCOMPANYING PAPERS AND ILLUSTRATIONS, ON AN INTERIM REPORT ON HURRICANE SURVEY OF PAWCATUCK, CONNECTICUT, AUTHORIZED BY PUBLIC LAW 71, 84TH CONGRESS, APPROVED JUNE 15, 1955



AUGUST 5, 1959.—Referred to the Committee on Public Works
and ordered to be printed with two illustrations.

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1959

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ILLUSTRATIONS ACCOMPANYING THE REPORT OF THE DIVISION ENGINEER (Only plates 1 and 2 & E-1 printed)

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LETTER OF TRANSMITTAL



DEPARTMENT OF THE ARMY
WASHINGTON 25, D. C.

July 30, 1959

The Speaker of the
House of Representatives

Dear Mr. Speaker:

I am transmitting herewith a favorable report dated 29 June 1959, from the Chief of Engineers, Department of the Army, together with accompanying papers and illustrations, on an interim report on hurricane survey of Pawcatuck, Connecticut, authorized by Public Law 71, 84th Congress, approved 15 June 1955.

In accordance with Section 1 of Public Law 534, 78th Congress, and Public Law 85-624, the views of the State of Connecticut and the Department of the Interior are set forth in the inclosed communications.

The Bureau of the Budget advises that there is no objection to the submission of the proposed report to the Congress; however, it states that no commitment can be made at this time as to when any estimate of appropriation would be submitted for construction of the project modification, if authorized by the Congress, since this would be governed by the President's budgetary objectives as determined by the then prevailing fiscal situation. A copy of the letter from the Bureau of the Budget is inclosed.

Sincerely yours,

Wilber M. Brucker

Wilber M. Brucker
Secretary of the Army

1 Incl
Rept w/accomp
papers & illus

COMMENTS OF THE BUREAU OF THE BUDGET

EXECUTIVE OFFICE OF THE PRESIDENT

BUREAU OF THE BUDGET

WASHINGTON 25, D. C.

July 24, 1959

The Honorable

The Secretary of the Army

My dear Mr. Secretary:

Assistant Secretary Short's letter of July 14, 1959, submitted the proposed interim report of the Chief of Engineers on a hurricane survey of Pawcatuck, Connecticut, authorized by Public Law 71, 84th Congress, approved June 15, 1955.

The Chief of Engineers recommends, subject to certain appropriate conditions of local cooperation, protection from storm tides for the Mechanic Street industrial area in Pawcatuck, comprising 31 acres, by the construction of a floodwall about 200 feet long and an earthfill dike about 2,400 feet long with necessary accessory works.

The estimated total cost for construction, based on 1958 prices, is \$585,000, of which \$409,000 is Federal and \$176,000, including a cash contribution of \$86,000, is local. Average annual benefits resulting primarily from prevention of flood damages are estimated at \$57,400. Annual charges are estimated at \$27,000, of which \$15,000 is Federal and \$12,000 is local. The stated benefit-cost ratio is 2.1.

I am authorized by the Director of the Bureau of the Budget to advise you that there would be no objection to the submission of the proposed report to the Congress. No commitment, however, can be made at this time as to when any estimate of appropriation would be submitted for construction of the project modification, if authorized by the Congress, since this would be governed by the President's budgetary objectives as determined by the then prevailing fiscal situation.

Sincerely yours,

Carl H. Schwartz, Jr., Chief
Resources and Civil Works Division

COMMENTS OF THE STATE OF CONNECTICUT

STATE OF CONNECTICUT
WATER RESOURCES COMMISSION
STATE OFFICE BUILDING HARTFORD 15, CONNECTICUT

June 17, 1959

E. C. Itschner, Major General, U.S.A.
Department of the Army
Office of the Chief of Engineers
Washington 25, D. C.

Re: ENCWID
Pawcatuck Hurricane
Protection

Dear General Itschner:

This will refer to your letter of 2 April 1959 requesting comments from this Commission concerning the interim report on hurricane survey of Pawcatuck, Connecticut as prepared by the Division Engineer.

The Fire District of Pawcatuck is exposed to intermittent damages from hurricanes and during the past years has suffered severe damages to persons and property.

We have reviewed the report referred to above together with its conclusions and recommendations. It is the feeling of this Commission that the recommended improvement for prevention of hurricane tidal damage would provide the most reasonable and practical protection for Pawcatuck. The report has the approval of this Commission.

Very truly yours,

/s/ William S. Wise
William S. Wise
Director

COMMENTS OF THE DEPARTMENT OF THE INTERIOR



UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON 25, D. C.

May 29, 1959

Dear General Itschner:

This is in reply to your letter of April 2 transmitting for our comments copies of your proposed report, together with the reports of the Board of Engineers for Rivers and Harbors, and of the Division Engineer, on an interim report on hurricane survey of Pawcatuck, Connecticut.

The U. S. Fish and Wildlife Service advises that the proposed construction would have insignificant effects upon fish and wildlife resources.

This Department has no objection to the recommended improvements.

Sincerely yours,

(sgd) Fred G. Aandahl

Assistant Secretary of the Interior

Maj. Gen. E. C. Itschner
Chief of Engineers
Department of the Army
Washington 25, D. C.

PAWCATUCK, CONNECTICUT

REPORT OF THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY



HEADQUARTERS
DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON 25, D. C.

29 June 1959

Subject: Pawcatuck, Connecticut

To: THE SECRETARY OF THE ARMY

1. I submit for transmission to Congress my interim report with accompanying papers on a survey of Pawcatuck, Connecticut, in partial response to Public Law 71, Eighty-fourth Congress, first session, approved June 15, 1955, directing the Secretary of the Army, in cooperation with the Secretary of Commerce and other Federal agencies concerned with hurricanes, to cause an examination and survey to be made of the eastern and southern seaboard of the United States under the direction of the Chief of Engineers, to include the securing of data on the behavior and frequency of hurricanes and determining methods of forecasting their paths and improving warning services, and determining possible means of preventing loss of human lives and damages to property, with due consideration of the economics of proposed breakwaters, seawalls, dikes, dams, and other structures, warning services, or other measures which might be required. This report considers only the tidal shores of Little Narragansett Bay and the Pawcatuck River in Rhode Island and Connecticut. Reports on other areas of the eastern and southern seaboard of the United States will be submitted later.

2. Pawcatuck, Connecticut, is on the west bank of the Pawcatuck River about 5 miles above its mouth. Westerly, Rhode Island, is on the east bank opposite Pawcatuck. The mean tidal range at the mouth of the river is about 2.5 feet. There are no existing or authorized hurricane projects in the area. The existing Federal navigation project provides for a channel 10 feet deep extending 7.5 miles from Stonington through Little Narragansett Bay, and up the river to Westerly, and a channel 10 feet deep extending from the river mouth 0.3 mile to a 16-acre project anchorage basin in Watch Hill Cove. Local interests have constructed numerous piers, wharves, and service facilities for small boats. The economy of Pawcatuck, which has a population of about 7,000, is centered

around manufacturing. Commerce on the river averages about 15,000 tons annually, mostly petroleum and petroleum products. The river is used extensively by recreational craft.

3. Hurricane losses in the area result chiefly from inundation by hurricane tides, action of storm waves, inundation caused by hurricane-induced rain, and wind action. Since 1770 the records indicate that 58 hurricanes have affected the area, of which 15 caused major tidal flooding, 15 caused moderate tidal flooding, and 28 were threats only. In addition, 21 other severe storms, not necessarily of tropical origin, have occurred since 1937, causing substantial tidal damages. A recurrence of the maximum hurricane tide of record, that of September 1938, under 1958 conditions would cause damages in the study area of \$2,600,000 of which about 50 percent would occur in the Mechanic Street industrial area of Pawcatuck. The average annual damages in that area are estimated at \$69,400, consisting of \$67,000 for lands and improvements and \$2,400 for costs of emergency preparation.

4. Local interests desire protection from storm tides and suggest a barrier along the outer banks to inclose Little Narragansett Bay, or a barrier across the river at Pawcatuck Rock about 2.5 miles above the mouth, both with provisions for navigation openings. They have stressed the need for protecting the Pawcatuck industrial area along the west bank of the river. Local interests have indicated willingness to comply with the requirements of local cooperation.

5. The Division Engineer finds that the cost of providing protection from storm tides for the entire area under consideration would be far greater than the benefits to be expected. But he finds that protection for the Mechanic Street industrial area in Pawcatuck, where nearly 50 percent of the area tidal damages occur, is warranted. He proposes a dike and accessory works for protection of this area and estimates the cost of the improvements, based on 1958 prices, at \$595,000 consisting of \$495,000 for construction, \$10,000 for preauthorization studies, and \$90,000 for lands, easements, rights-of-way, and relocations. The annual charges would be \$27,000, including \$5,800 for maintenance and operation. The average annual benefits are estimated at \$57,400, consisting of \$55,000 for prevention of damages and \$2,400 for elimination of cost of emergency preparations. The benefit-cost ratio is 2.1. The Division Engineer recommends authorization of the improvement subject to certain conditions of local cooperation.

6. The President of the Beach Erosion Board concurs in the view of the Division Engineer that the dikes in the recommended plan will not cause accretion or erosion along the adjacent shoreline.

7. The Board of Engineers for Rivers and Harbors concurs in the views and recommendations of the reporting officer and in the views of the President of the Beach Erosion Board. It accordingly recommends the improvements as proposed by the Division Engineer.

8. After due consideration of these reports, I concur in the views and recommendations of the Board of Engineers for Rivers and Harbors. I therefore recommend improvements for prevention of hurricane damages at Pawcatuck, Connecticut, to consist of a floodwall extending about 200 feet from the New York, New Haven and Hartford Railroad eastward to Mechanic Street about 100 feet north of the Bostitch Company plant; an earthfill dike about 2,400 feet long extending from Mechanic Street to the riverbank and thence southward along the river to high ground south of the Cottrell Company plant; two stoplog closures across Mechanic Street; and a pumping plant for interior drainage; all generally in accordance with the plans of the Division Engineer and with such modifications thereof as in the discretion of the Chief of Engineers may be advisable; at an estimated first cost of \$585,000, consisting of \$495,000 for construction and \$90,000 for lands, easements, rights-of-way, alterations, and relocations; provided that, prior to initiation of construction, local interests give assurances satisfactory to the Secretary of the Army that they will: (a) provide without cost to the United States all lands, easements, and rights-of-way necessary for construction of the project; (b) accomplish without cost to the United States all alterations and relocations of buildings, streets, storm drains, and utilities made necessary by reason of the construction; (c) bear 30 percent of the total first cost, a sum presently estimated at \$176,000 to consist of the items listed in (a) and (b) above and a cash contribution now estimated at \$86,000, the cash to be paid in a lump sum prior to commencement of construction and the final allocation of cost to be made after actual costs and values have been determined; (d) hold and save the United States free from damages due to the construction works; and (e) operate and maintain all the works after completion in accordance with regulations prescribed by the Secretary of the Army. The net cost to the United States for the recommended plan of improvement is estimated at \$409,000 for construction.



E. C. Itschner
Major General, USA
Chief of Engineers

REPORT OF THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS

Subject: Pawcatuck, Connecticut

824.02(Pawcatuck, Conn. - Hurricane Study)

2d Ind.

The Board of Engineers for Rivers and Harbors, Washington 25, D. C.,
13 March 1959

To: The Chief of Engineers, Department of the Army

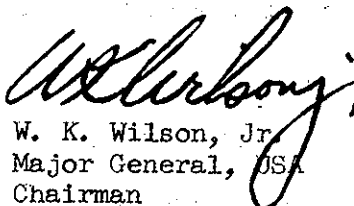
1. The Division Engineer issued a notice informing the public of his recommendations and giving interested parties an opportunity to furnish additional information to the Board. No communications have been received.

2. The Board concurs generally in the views and recommendations of the Division Engineer. Although more than 1,500 acres along the shores of Little Narragansett Bay and the tidal reach of Pawcatuck River in Rhode Island and Connecticut are subject to inundation from tides induced by hurricanes and other storms, protection of only a 31-acre area in Pawcatuck is economically justified at this time. The recommended improvement is suitable, is economically justified and warrants Federal participation in its construction. The Board agrees with the President of the Beach Erosion Board that the proposed improvements will not be detrimental to adjacent shorelines.

3. Accordingly, the Board recommends improvements for prevention of hurricane tidal damages at Pawcatuck, Connecticut, to consist of a flood-wall extending about 200 feet from the New York, New Haven and Hartford Railroad eastward to Mechanic Street about 100 feet north of the Bostitch Company plant; an earthfill dike about 2,400 feet long extending from Mechanic Street to the riverbank and thence southward along the river to high ground south of the Cottrell Company plant; two stoplog closures across Mechanic Street; and a pumping plant for interior drainage; all generally in accordance with the plans of the Division Engineer and with such modifications thereof as in the discretion of the Chief of Engineers may be advisable; at an estimated first cost of \$585,000, consisting of \$495,000 for construction and \$90,000 for lands, easements, rights-of-way, alterations, and relocations; provided that, prior to initiation of construction, local interests give assurances satisfactory to the Secretary of the Army that they will: (a) provide without cost to the United States all lands, easements, and rights-of-way necessary for construction of the project; (b) accomplish without cost to the United States all alterations and relocations of buildings, streets, storm drains, and utilities made necessary by reason of the construction; (c) bear 30 percent of the total first cost, a sum presently estimated at \$176,000 to consist of the items listed in (a) and (b) above and a cash contribution now estimated at \$86,000, the cash to be paid in a lump sum prior to commencement of construction and the final allocation of cost to be made after actual costs and values have been determined; (d) hold and save the United States free

from damages due to the construction works; and (e) operate and maintain all the works after completion in accordance with regulations prescribed by the Secretary of the Army. The net cost to the United States for the recommended plan of improvement is estimated at \$409,000 for construction.

For the Board:


W. K. Wilson, Jr.
Major General, USA
Chairman

REPORT OF THE DIVISION ENGINEER

GLOSSARY

HURRICANE SURGE: the mass of water causing an increase in the elevation of the water surface above predicted astronomical tide at the time of a hurricane; it includes wind setup; sometimes the maximum increase in elevation is referred to as the surge.

HURRICANE TIDE: the rise and fall of the water surface during a hurricane exclusive of wave action.

KNOT: a velocity equal to one nautical mile (6080.2 feet) per hour (about 1.15 statute miles per hour).

PONDING: the storage of water behind a dike or wall from local runoff.

SPRING TIDE: a tide that occurs at or near the time of new and full moon and which rises highest and falls lowest from the mean level.

STANDARD PROJECT HURRICANE: A storm that may be expected from the most severe combination of meteorologic conditions that are considered reasonably characteristic of the region involved, excluding rare combinations.

STILLWATER LEVEL: the elevation of the water surface if all wave action were to cease.

STORM SURGE: same as "hurricane surge".

REPORT OF THE DIVISION ENGINEER

SYLLABUS

The Division Engineer finds that a serious problem of flooding from hurricanes and storms exists in the principal industrial area of Pawcatuck, Connecticut. The acuteness of the problem is indicated by the fact that total flood damages of over \$2,000,000, at 1958 price levels, would result from a recurrence of the two recent severe hurricanes, September 1938 and August 1954, in the area of proposed protection.

The Division Engineer recommends the construction of a dike and land wall system extending along the west bank of the Pawcatuck River which would provide local protection for the principal industrial area of Pawcatuck, in the Town of Stonington, Connecticut. The estimated first cost is \$585,000, of which \$409,000 is the cost to the United States.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
150 CAUSEWAY STREET
BOSTON 14, MASS.

6 October 1958

SUBJECT: Interim Report on Hurricane Survey,
Pawcatuck, Connecticut

TO: Chief of Engineers
Department of the Army
Washington 25, D. C.
ATTENTION: ENGWF

AUTHORITY

1. This report is submitted in partial compliance with authorization contained in Public Law 71, 84th Congress, 1st session, adopted 15 June 1955, which reads:

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in view of the severe damage to the coastal and tidal areas of the eastern and southern United States from the occurrence of hurricanes, particularly the hurricanes of August 31, 1954, and September 11, 1954, in the New England, New York, and New Jersey coastal and tidal areas, and the hurricane of October 15, 1954, in the coastal and tidal areas extending south to South Carolina, and in view of the damages caused by other hurricanes in the past, the Secretary of the Army, in cooperation with the Secretary of Commerce and other Federal agencies concerned with hurricanes, is hereby authorized and directed to cause an examination and survey to be made of the eastern and southern seaboard of the United States with respect to hurricanes, with particular reference to areas where severe damages have occurred.

SEC. 2. Such survey, to be made under the direction of the Chief of Engineers, shall include the securing of data on the behavior and frequency of hurricanes, and the determination of methods of forecasting their paths and improving warning services, and of possible means of preventing loss of human lives and damages to property, with due consideration of the economics of proposed

breakwaters, seawalls, dikes, dams, and other structures, warning services, or other measures which might be required."

SCOPE

2. SCOPE OF STUDIES

This interim report of survey scope presents the results of an examination and survey of hurricane and other storm-induced tidal flooding in the principal industrial section of Pawcatuck, Connecticut. It is one in a series of reports which, when completed, will constitute a survey of the entire coastal area of New England subject to tidal flooding due to hurricanes and other great storms.

This report includes data on climatology, hydrology, and tidal flood damages; a summary of the historical occurrences of hurricanes and other severe storms; and a description, together with estimates of costs and benefits, of a recommended plan of improvement which will provide protection against tidal flooding, as well as fresh water flooding.

Field work has consisted of flood damage investigations, topographic and hydrographic surveys in the area of considered protective works, and subsurface explorations to determine the nature and characteristics of underlying material.

3. COORDINATION

State officials and local interests have been consulted frequently during the course of the study, and the work has been coordinated and discussed with appropriate Federal agencies. The views of local interests were considered in arriving at a practicable and economic means of providing needed protection. A public hearing has been held to acquaint all interested parties with the results of the survey and to enable them to present their views and comments thereon. Coordination with other agencies is discussed in further detail in paragraph 74.

PRIOR REPORTS

4. HURRICANE REPORTS

There are no previous reports by the Corps of Engineers on the specific subject of hurricane protection for the Pawcatuck area. Part Two, Chapter XXXIX (unpublished) of the report (Senate Document No. 14, 85th Congress, First Session), on the "Land and Water Resources of the New England-New York Region", prepared by the New England-New York Inter-Agency Committee, pursuant to

Presidential directive of October 9, 1950, includes a brief history of hurricane occurrences in New England, a description and summary of experienced losses in recent hurricanes, and a discussion of several methods of reducing damages.

5. NAVIGATION REPORTS

The Pawcatuck River and Little Narragansett Bay have been the subject of many published and unpublished reports since 1871. The following reports form the basis for the existing navigation project:

- a. House Document No. 62, 54th Congress, First Session; authorized June 3, 1896.
- b. Specified in Act, March 3, 1905.
- c. House Document No. 49, 71st Congress, Second Session, 1929.
- d. House Document No. 839, 76th Congress, Third Session; authorized March 2, 1945.

DESCRIPTION

6. LOCATION AND EXTENT OF AREA

Pawcatuck is located in the Town of Stonington, New London County, Connecticut, on the west bank of the Pawcatuck River which is a common boundary line for the States of Rhode Island and Connecticut. It is approximately 15 miles east of New London, Connecticut, and about 45 miles west of Newport, Rhode Island at the mouth of Narragansett Bay. Westerly, Rhode Island is located across the river from Pawcatuck on the east bank of the Pawcatuck River. The area of study is the tidal reach of the Pawcatuck River and Little Narragansett Bay, which is the mouth of the river. The principal industrial area of Pawcatuck is about 5 miles upstream from the mouth of the Pawcatuck River, placing it in the area of tidal flooding and inundation from the Atlantic Ocean.

7. PAWCATUCK RIVER

The Pawcatuck River rises in Worden Pond in the western part of South Kingstown, Rhode Island, and follows a meandering course, first generally west about 25 miles and then south about 8 miles, to its mouth at Little Narragansett Bay, an arm of Fishers Island Sound which in turn is an arm of the Atlantic Ocean. The river has a total fall of approximately 90 feet from its headwaters to the sea. It is tidal and navigable to Westerly, Rhode Island, a distance of about five miles. The lower ten miles of the river forms a common boundary between the States of Connecticut and Rhode Island. Drainage area at the mouth of the river is 303 square miles.

8. TIDES

The mean tidal range is 2.5 feet at the mouth of the Pawcatuck River. Spring tides have an average range of 3.1 feet and a maximum range of about 5.0 feet. The time interval for a complete tidal cycle averages about 12 hours and 25 minutes. This results in the daily occurrence of two low and two high waters on an average of six out of every seven days. The U. S. Geological Survey river gaging station, located about six miles from the mouth of the river or about one mile above Pawcatuck, indicates that only the high tide of the cycle affects the water surface at the gage during low flow conditions.

9. GEOLOGY

Pawcatuck, Connecticut, lies on the seaboard lowland of the New England physiographic province, on the west bank of the upper tidal portion of the Pawcatuck River. Seaward, the river is navigable with a 10-foot channel and empties 4 miles downstream into Little Narragansett Bay, at the juncture of Fishers Island Sound and Block Island Sound. A prominent glacial till headland, Watch Hill, Rhode Island, provides great protection from storm waves. The headland is part of a glacial terminal moraine, the Harbor Hill moraine, which runs along the entire Rhode Island coast west of Narragansett Bay, departs seaward at Watch Hill, appears in the form of Fishers Island, submerges again, and reappears to form the northern backbone of Long Island. It is responsible for the existence of the Pawcatuck River, because the resistant and impervious moraine serves as a giant dam, preventing normal direct seaward drainage from the entire coastal area of western Rhode Island, resulting in drainage diverted to the west through Pawcatuck.

10. AREA MAPS

The area under study appears on standard quadrangle sheets of the U. S. Geological Survey, at scales of 1:62,500 and 1:31,680, and on a general map of the States of Massachusetts, Rhode Island, and Connecticut, at a scale of 1:500,000, which has been published by the Geological Survey. The Army Map Service has issued a series of topographic maps of which one, entitled Providence (NK 19-7), covers the entire watershed at a scale of 1:250,000. Another series covers the entire area of the basin at a scale of 1:25,000. The watershed is also shown on the Rhode Island and Connecticut Transportation Maps, scale 1:250,000, issued by the U. S. Public Roads Administration. The coastal area of the basin and the navigable portion of the Pawcatuck River are shown on U. S. Coast and Geodetic Survey Charts Nos. 358 and 1211. A "Geologic Map Index of Massachusetts, Rhode Island and Connecticut," scale

1:500,000, dated 1952, showing areas covered by published geologic maps, has been issued by the U. S. Geological Survey.

ECONOMIC DEVELOPMENT

11. POPULATION

The population of Pawcatuck in 1950, based on U. S. Bureau of the Census figures, was 5,269. This represents a population increase of about 12 percent since 1940. An estimate by the Connecticut Health Department in 1957 indicated the population had increased to about 7,000. This trend is expected to accelerate with the continued development of New London County and the anticipated increase in industry in the Pawcatuck-Westerly area. A recent study made by the University of Connecticut reveals that about 74 percent of the growth since 1950 was attributable to migration and the balance to natural increase.

12. INDUSTRY

Manufacturing has long been the base of the economy of Pawcatuck. There are two large manufacturing establishments in Pawcatuck, although one is inoperative at the present. The other factory manufactures printing presses, accessory machinery, shapers, drills and rocket motors. The inoperative plant produced stapling machines and staples until early in 1957 when operations were transferred to a new plant in Rhode Island. During the approximately ten-year period that the company operated in Pawcatuck, it was estimated that its production increased five fold. The company still maintains the plant, although it is available for rent at present. In 1956, these two companies employed approximately 1,450 people, or about 50 percent of the total number of persons employed in manufacturing in the Town of Stonington. The total annual manufacturing payroll for Stonington in 1956 was in excess of \$11,000,000.

13. TERMINAL FACILITIES

A commercial landing dock with a frontage of 500 feet and bulk oil tank storage facilities 500 x 1,000 feet is located on Mechanic Street in Pawcatuck. There are two public landing docks in Pawcatuck, one with a 200-foot frontage. A town dock is located in the Avondale section of Westerly, Rhode Island. The three public wharves in Watch Hill Cove have dockage space of about 350 feet. The Watch Hill Yacht Club has a wharf with dockage space 45 x 100 feet and two floats 12 x 30 feet. The Westerly Yacht Club, located on Watch Hill Road in Westerly, Rhode Island, has four docks varying in length 60-112 feet. No facilities for handling heavy freight exist in Little Narragansett Bay or on

the Pawcatuck River, however, there are a few bulkheads and wharves for commercial use. Storage facilities are available for about 685 boats. A marine engine repair shop is located on one of the lower wharves at Westerly. Five private wharves are in use near the head of navigation. There are no regular water lines of transportation.

14. AGRICULTURE

Agriculture has only a minor roll in the economy of the Town of Stonington, consisting principally of dairying and truck-farming on small holdings. It is of very little importance in the Pawcatuck area, especially the areas inundated by hurricane tides.

15. POWER

The survey area is served by the Mystic Power Company, a subsidiary distributing company of the New England Electric system. The transformer station is located in Westerly, Rhode Island, across the river from Pawcatuck.

16. NAVIGATION

Navigation in the Pawcatuck River is confined to Little Narragansett Bay and to the tidal reaches of the River. The tidal portion of the River is navigable to Westerly, Rhode Island, a distance of about five miles. The annual amount of commerce in the Pawcatuck River during the past 10 years (1947-1956) amounted to about 15,000 tons, consisting primarily of petroleum and petroleum products. The vessels presently carrying the commerce are motor vessels with drafts ranging from 3 to 11 feet. There were 114 vessel trips reported in 1952. Seven of the vessels had drafts of 11 feet and nine had drafts of 10 feet. The waters of Little Narragansett Bay and the Pawcatuck River are also used extensively, especially during the summer months, by recreational craft ranging in size from small motor boats to large yachts of 100 feet or more in length and up to seven feet in draft.

17. TRANSPORTATION

The area is served by a network of modern highways and secondary roads. The two principal routes are U. S. No. 1 which passes through Pawcatuck in an east-west direction and connects with Connecticut Routes 2 and 3 which run northeast and northwest from Pawcatuck. The main line of the New York, New Haven and Hartford Railroad from Boston to New York provides daily passenger and freight service for the Pawcatuck-Westerly area, with the station located just across the river in Westerly, Rhode Island. The Trumbull Airport, about 12 miles southwest of Pawcatuck, and the Westerly State Airport, Rhode Island, about one mile southeast of Pawcatuck, accommodate the Pawcatuck area.

18. RECREATION

The Pawcatuck River and Little Narragansett Bay are important recreational areas serving large population centers in Rhode Island, Connecticut, and southern Massachusetts. Fishing, boating and bathing facilities are available along both shores of the river, near the mouth and in the Bay. Striped bass, blackfish, weakfish and flatfish abound in the offshore waters. Numerous yacht clubs and boat yards provide innumerable opportunities for the sailing and motor-boating enthusiasts. Extensive public bathing beaches are located near Watch Hill as well as in Stonington, providing a choice of either ocean surf or quiet, protected salt water swimming. The increasing growth of the tourists demands is resulting in the creation of more and more recreational facilities.

19. POLLUTION

Storm sewer systems are provided within the Pawcatuck Fire District which includes the survey area of Pawcatuck. Sanitary sewage is disposed of by river dilution and private septic systems. The Pawcatuck District has completed plans for a new sewage disposal plant approved by the Connecticut State Water Resources Commission and the State Department of Health.

20. FISHERIES

There is no sport fishing in the immediate harbor area; however, in the area immediately offshore from Little Narragansett Bay can be found winter flounder, summer flounder, scup, butterfish, striped bass, mackerel, cod, tuna, bluefish and weakfish. Both commercial and recreational use is made of these fishery resources. Little Narragansett Bay and the tidal portion of the Pawcatuck River is the source of salt and brackish water fish and shellfish.

CLIMATOLOGY

21. CLIMATE

The Pawcatuck area has a temperate and changeable climate marked by four distinct seasons which are characteristic of its latitude and of New England. Owing to the moderating influence of Long Island Sound and the Atlantic Ocean and particularly to the variable movements of high and low pressure systems approaching from the west or southwest, extremes of either hot or cold weather are rarely of long duration. In the winter, coastal storms frequently bring rainfall, in contrast to snow in the more northerly areas of Connecticut. In the summer, cooling relief from hot, humid weather is provided by sea breezes from the south,

thunderstorms from the west, and cool air from the north. The prevailing winds are northwesterly in the winter and southwesterly in the summer. High winds, heavy rainfall, and abnormally high tides occur with unpredictable frequency. Hurricanes can be expected especially during the months of August, September, and October.

No official climatological records have been maintained at Pawcatuck; however, an official U. S. Weather Bureau station has been maintained at New London, Connecticut, approximately 15 miles west. Appendix B contains detailed information on climatology, based on published records of the U. S. Weather Bureau station at New London, Connecticut.

22. TEMPERATURE

The average annual temperature of the New London area, based on records for the period 1871 to 1954 is approximately 50°F. February, the coldest month, has a mean temperature of 29.8°F, and July, the warmest month, has a mean temperature of 71.7°F. Freezing temperatures, which are common from late November through March, occur on an average of 100 to 120 days a year. The lowest temperature recorded in the New London area was -17°F on 9 February 1934, and the highest temperature was 100°F on 26 August 1948. The monthly mean, maximum and minimum temperatures at the U. S. Weather Bureau Station, New London, are given in Table B-1, Appendix B.

23. PRECIPITATION

The mean annual precipitation over the New London area during the past 84 years (1871-1954) has ranged from a minimum of 30.05 inches in 1896 to a maximum of 60.62 inches in 1919. The mean annual rainfall amounts to about 44.6 inches and is rather evenly distributed throughout the year. Measurable precipitation occurs on an average about 120 to 125 days out of the year, or one day out of three. Average monthly rainfall varies between 4.39 inches for August and 3.09 inches for June. Extremes of monthly precipitation have ranged from 16.44 inches in August 1874 to 0.01 inch in June 1949. Annual snowfall based on 34 years of record averages 33.9 inches. A summary of monthly precipitation data at New London is contained in Table B-2, Appendix B.

RUNOFF AND STREAMFLOW DATA

24. Records of streamflow at three locations in the Pawcatuck River basin have been obtained by the U. S. Geological Survey for various periods of time since December 1939. One of these gages, with a drainage area of 295 square miles, is situated about one mile upstream of Pawcatuck. A summary of peak discharge is contained in Table B-3, Appendix B.

HISTORY OF HURRICANES AND OTHER GREAT STORMS

25. HISTORICAL HURRICANES AND GREAT STORMS

Descriptions of hurricanes and other severe storms affecting southern New England can be found in the earliest records of the Massachusetts Bay Colony. Governor William Bradford's "History of Plymouth Plantation, 1620-1647" describes a violent storm that occurred along the coast of southern New England on 15 August 1635. Another great hurricane, on 3 August 1638, is described by John Winthrop in his "History of New England from 1630 to 1649". Although there is no record to indicate that these two storms affected Long Island Sound or Fishers Island Sound, it is reasonable to assume, on the basis of present knowledge of the nature of the hurricane surge, that these storms caused inundation of lowlands along the coast of Connecticut.

The first reference to a violent storm in Connecticut is contained in John Winthrop's Journal "History of New England 1630-1649". Referring to the storm of 16 March 1639, he wrote, "there was so violent a wind at south-southeast and south as the like was not since we came into this land. It began in the evening and increased till midnight. . . . It tare down fences - people ran out of the houses in the night. . . . There came such a rain withal, as raised the waters at Connecticut 20 feet above their meadows. The Indians near Aquiday being pawpawing in this tempest, the devil came and fetched away 5 of them". Early newspapers and diaries between 1770 and 1900 contain a number of references to severe storms in Connecticut. The four most notable storms during this period are those of 19 August 1788, 23 September 1815, 3 September 1821, and 24 August 1893. Accounts of tidal flooding along the Connecticut coast in severe storms, other than hurricanes, have been recorded since 1767. Tide gage records at a number of localities along the coast of Connecticut are available which indicate the height of tidal flooding experienced during the past 20 years.

26. RECENT HURRICANES AND GREAT STORMS

More numerous records are available of hurricanes and other storms that have caused tidal flooding along the Connecticut coast subsequent to 1900, with good records available for the years since 1930. Among the best known storms during the past 28 years, all of which caused tidal flooding of damaging proportions in the New England area, are the following:

<u>HURRICANES</u>	<u>OTHER STORMS</u>
a. 21 September 1938	a. 25 November 1950
b. 31 August 1954 (Carol)	b. 16 March 1953
c. 14 September 1944	c. 17 October 1955
d. 12 September 1954 (Edna)	

Further data on the history of hurricanes are contained in Appendix A.

27. HURRICANE FREQUENCY

The distribution of recorded hurricane occurrences along the Connecticut coast, by estimated degrees of intensity, is shown in Table 1.

TABLE 1

RECORDED HURRICANE OCCURRENCES CONNECTICUT COAST

<u>Category</u>	<u>Years</u>			<u>Total</u>
	<u>1770-1800</u>	<u>1801-1900</u>	<u>1901-1957</u>	
A. Caused severe tidal flooding	1	7	7	15
B. Damage from wind and rainfall (usually accompanied by high seas and moderate tidal flooding)	2	5	8	15
C. Threatened area	<u>1</u>	<u>4</u>	<u>23</u>	<u>28</u>
TOTAL	4	16	38	58

The fact that there is a record of 38 hurricane experiences thus far in the 20th century (1901-1957), as compared with 20 occurrences in the 131-year period between 1770 and 1900, is believed to be due to a lack of records on storm occurrences prior to 1900 rather than a trend toward increased hurricane activity in recent years.

Records indicate that the Connecticut coastal area has experienced severe tidal flooding from hurricanes upon seven occasions since 1900. In addition, storm tides have caused flooding on at least 21 occasions since the first of 1938. An elevation-frequency curve (see Plate B-8, Appendix B) for combined tidal plus fresh water elevations has been prepared for Pawcatuck based on (1) known elevations of tidal flooding at Pawcatuck and the Westerly business center for Hurricane "Carol", August 1954; (2) known elevation of tidal flooding at the Westerly business center for the Hurricane of September 1938; and (3) water-stage data for the period 27 November 1940 to 10 December 1957, as recorded at the U. S. Geological Survey river gaging station located about one mile upstream from Pawcatuck on the east bank of the Pawcatuck River.

With respect to seasonal variation of hurricane occurrences in southern New England, the period of greatest activity extends from early August to the end of October. However, records indicate occurrences as early as the middle of June and as late as the middle of December.

HURRICANE CHARACTERISTICS

28. GENERAL DESCRIPTION

The term "hurricane" is applied to an intense cyclonic storm originating in tropical or subtropical latitudes in the Atlantic Ocean north of the Equator. Accumulation of heat close to the surface of the water provides energy for water vaporization and the movement of masses of moist tropical air. A hurricane is characterized by low barometric pressures, high winds (75 miles per hour or greater), heavy clouds, torrential rain, tremendous waves, and tidal surges.

29. ORIGINS AND TRACKS

Most of the hurricanes that have affected the eastern coast of North America have formed either near the Cape Verde Islands or in the western Caribbean Sea. Cape Verde hurricanes move westerly for a number of days with a forward speed of about 10 miles per hour. Occasionally, they proceed straight to the coast

of Texas, but generally, after reaching the middle Atlantic Ocean, they recurve northerly and then easterly. Frequently they cross the West Indies, sometimes striking the eastern coast of the United States between Key West, Florida, and Cape Cod, Massachusetts. After recurving the storms usually increase their forward speed to a rate of 25 to 30 miles per hour and occasionally to a speed of 60 miles per hour. The hurricanes which form in the Caribbean Sea generally move in a northerly direction, travel across Cuba, then strike either the Gulf or the southeastern shores of the United States. The hurricanes that most severely affect New England usually approach from the south-southwest after recurving east of Florida and skirting the Middle Atlantic states. The paths of a number of selected hurricanes are shown on Plate A-1, Appendix A.

30. WINDS AND BAROMETRIC PRESSURE

The highest winds of a hurricane are those within a circular region extending from the edge of the "eye", or calm center, outward for 10 to 15 miles. The diameter of the eye is usually about 15 miles, although the eye of a mature hurricane may frequently be 20 to 30 miles in diameter. Wind movement is not directly toward the low pressure cyclone center or eye of the hurricane but approaches the center in a counter-clockwise spiral. Consequently, the highest wind velocities occur at points to the right of the hurricane's center where the spiral wind movement and the forward motion of the storm are in the same direction. Since destruction by the wind is greatest in the area on the right side of the hurricane, this area is known as the "dangerous semi-circle". A hurricane following a track over New London, Connecticut, west of Pawcatuck, would place Pawcatuck in this "dangerous semi-circle".

Atmospheric pressure falls rapidly as the center of the hurricane approaches and as the velocity of the wind increases. Minimum barometric readings do not always occur in the center of the eye. In some instances, the minimum is reached at the beginning of the calm period, while in others, the minimum is reached at the end of the calm period. Usually the barometric low is about two inches below the normal sea level pressure of 30 inches. However, in several hurricanes, pressures as low as three inches below normal have been recorded. The lowest barometric pressure of record in the United States, 26.35 inches, was recorded at the northern end of Long Key, Florida on 2 September 1935.

31. RAINFALL

Another characteristic of a hurricane is the heavy rainfall that usually accompanies the storm. The rainfall at the edge of the disturbance is light, normally in the form of showers. As the center approaches, the showers increase in frequency and intensity, becoming heavy to excessive near the eye. The heaviest rain usually falls ahead of the eye, driving torrentially from spiral bands of clouds that sometimes produce nearly two inches of rain per hour. For a 24-hour period, amounts approaching 20 inches are not uncommon. In New England, the hurricane of September 1938 caused rainfall of 6 to 8 inches in a one-day period at a number of locations; in the 1954 hurricane, one-day rainfalls of 4 to 5 inches were recorded. The record rainfall in New England, associated with a hurricane, occurred during Hurricane "Diane" (August 1955) when a rainfall of 15.7 inches in 24 hours (total storm rainfall of 19.8 inches in 48 hours) was experienced at Westfield, Massachusetts, about 70 miles northwest of Pawcatuck. This hurricane, however, had lost its typical characteristics - high winds and tidal surge - by the time it reached and stalled over New England.

32. WAVES

Much of the hurricane damage is caused by waves generated by the winds. The ultimate size of the waves depends on the force and duration of the wind and the fetch or distance the wave travels. No waves of any significance are expected to reach Pawcatuck. Any hurricane induced waves that strike the coastline near the mouth of the river would be dissipated by the numerous bends and restrictions of the river channel in the five-mile reach between the mouth and Pawcatuck.

33. TIDAL SURGES

Flooding results from the movement of the storm surge, or rise in water level, onto a shoaling coast or into a bay or inlet. The surge is caused by a combination of hurricane winds and low barometric pressure in a storm having a track and speed of forward movement synchronized with the normal pattern of tidal movement and oscillations of the sea in the open ocean.

Generally the rise of the sea is gradual as the center of the storm approaches but sometimes it comes with great swiftness. The history of terrible storms, revealing many instances of cities and towns flooded, with thousands of lives lost, gives graphic evidence that such rises are not always gradual.

Usually the level of the storm surge is increased by a rising ocean bed and favorable shore contours, factors which similarly affect the astronomical tide in shore locations. The ordinary rise of the tide amounts to only one or two feet in the open ocean while its range is often ten to twelve feet at coastal points. In certain bays and channels the normal rise is 25 to 50 feet above low water. The times of ebb and flow of such tides are of course well known, but the storm surge comes so rarely to any one community that it is seldom anticipated in its fully developed form. A well defined storm surge is not developed unless the slope of the ocean bed and the contour of the coastline are favorable to its rise, in combination with the proper direction of the storm track and speed of movement. Tidal flooding along the Connecticut coast occurs as the storm surge accompanying northward-moving hurricanes, passing west of Pawcatuck, is directed up Long Island Sound from its eastern end. The time lag for the surge to reach the western end of the Sound is approximately three hours.

DESIGN HURRICANE TIDAL FLOOD

34. WIND FIELD AND BAROMETRIC PRESSURE

In New England, the maximum recorded wind velocity in a past hurricane is a gust of 186 m.p.h. at the Blue Hill Observatory, Milton, Massachusetts, in September 1938. The sustained 5-minute velocity at this location, about 80 miles northeast of Pawcatuck, during this same hurricane was 121 m.p.h. At New Haven (about 65 miles west of Pawcatuck) and Hartford, Connecticut, (about 60 miles northwest of Pawcatuck) sustained winds of 38 and 46 m.p.h., respectively, were recorded with gusts of 46 and 59 m.p.h. respectively, in 1938.

During the hurricane of September 1944, the maximum gust in New England was an estimated 109 m.p.h. at Hartford, Connecticut. At New Haven, Connecticut, the recorded maximum gust was 65 m.p.h. and the sustained 5-minute wind was 33 m.p.h.

Peak gusts measured during Hurricane "Carol", 31 August 1954, are 142 m.p.h. at Mount Washington, New Hampshire, about 225 miles northeast of Pawcatuck, and 135 m.p.h. at Block Island, Rhode Island, about 20 miles southeast of Pawcatuck. Gusts of 65 and 64 m.p.h., respectively, were experienced at New Haven and Hartford, Connecticut.

Low atmospheric pressures are characteristic of the "eye" of a hurricane. The minimum in New England was 28.04 inches recorded at Hartford, Connecticut, during the 1938 hurricane. The lowest pressure recorded in New England during the 1944 hurricane was 28.31 inches at Point Judith, Rhode Island, about 20 miles east of Pawcatuck. In Hurricane "Carol", August 1954, a pressure of 28.20 inches was recorded at Storrs, Connecticut, about 40 miles north-west of Pawcatuck. No records of barometric pressures have been obtained at Pawcatuck. Further data on wind velocities and barometric pressures in past hurricanes are included in Appendix B.

35. ASTRONOMICAL TIDE AND TIDAL FLOODING

An important factor in determining the height of flooding from a tidal surge is the stage of the normal tide at the time the hurricane surge arrives at the coast. The surge in the September 1938 hurricane added 9.5 feet to the astronomical tide at the mouth of the Pawcatuck River and caused flooding to an elevation of 10.4 feet, m.s.l. at this location. The hurricane of 31 August 1954 (Carol), with an 8.2-foot surge, caused flooding to an elevation of 9.7 feet, m.s.l. at the mouth of the Pawcatuck River. Hurricane high-water elevations, predicted coincident astronomical tides, and the storm surges in the two major hurricanes to strike this area in recent times, are tabulated in Table 2.

TABLE 2
TIDAL FLOOD DATA
MOUTH OF PAWCATUCK RIVER
NEAR WATCH HILL, RHODE ISLAND

<u>Date</u>	<u>Time of Peak (E.S.T.)</u>	<u>Hurricane High-Water Elevation (feet, m.s.l.)</u>	<u>Coincident Astronomical Tide (feet, m.s.l.)</u>	<u>Hurricane Surge (feet)</u>
21 Sept. 1938	4:20 P.M.	10.4	0.9	9.5
31 Aug. 1954	9:30 A.M.	9.7	1.5	8.2

The duration of tidal flooding, above the elevation of mean high water, was about 6 hours in the hurricane of 31 August 1954. Further data on tidal high water elevations may be found in Appendix B.

Peak flooding at the mouth of the Pawcatuck River in the 1938 hurricane occurred about 1 hour and 50 minutes before a predicted astronomical high tide of 1.7 feet, m.s.l.; and the 1954 hurricane occurred about twenty minutes before a predicted high tide of 1.5

feet, m.s.l. The greatest surge was 9.5 feet in the hurricane of 1938. The surge in the August 1954 hurricane was 1.3 feet less than that of 1938 and the elevation of tidal-flooding in 1954 was only 0.7 foot below the 1938 level due to the high stage of tide at the time of peak flooding. Had the surge in the 1954 hurricane been equal in magnitude to that of the 1938 hurricane, flooding in 1954 would have reached an elevation of 11.0 feet, m.s.l. or 1.3 feet higher than was actually experienced. If these two hurricanes had struck the mouth of the Pawcatuck River coincident with a high spring tide of 2.5 feet, m.s.l., flooding would have been experienced to an elevation of 12.0 feet, m.s.l. in 1938, and 10.7 feet, m.s.l. in 1954; or 1.6 and 1.0 feet higher, respectively.

In determining future tidal-flood levels, one factor to be considered is the rise in mean sea level that is taking place along the New England coast. Continuing investigations being made by the U. S. Coast and Geodetic Survey in regard to changes in sea level indicate that the elevation of mean sea level has risen at a rate of approximately 0.02 foot per year since 1930. (See report by the Council on Wave Research in Proceedings of the First and Second Conferences on Coastal Engineering, 1952). If this trend continues and storms of the magnitude of the 1938 and 1954 hurricanes were to occur at the end of the next 50 years, flood levels would be approximately one foot higher than were actually experienced in these storms. The rising sea level is important in the severity of future hurricane tidal flooding.

36. STORM TRACKS

The hurricane of 21 September 1938 followed a path about 60 miles west of Pawcatuck, thereby placing Pawcatuck in the sector of the strongest and most damaging hurricane winds. The hurricanes of 31 August 1954 and 14 September 1944, with paths located 5 miles west and 15 miles east of Pawcatuck, did not produce severe winds in this area. Due mainly to the relation between the hurricane tracks and the mouth of Long Island Sound, storm surges moving up the Sound were highest in the 1938 hurricane with the 1954 next in magnitude.

37. SELECTION OF DESIGN HURRICANE

In the design of protective works for Pawcatuck, structures must be of sufficient height and strength to withstand the most severe storm tide that can reasonably be expected. A design hurricane for use in determining the required height of protective structures has been established through the cooperation of the U. S. Weather Bureau and the Beach Erosion Board, assisted by personnel of the Agricultural and Mechanical College of Texas.

The basis for the design storm is a transposition of the September 1944 hurricane. This storm, when it was off Cape Hatteras, had the greatest amount of energy of any known hurricane along the Atlantic Coast. However, the 1944 hurricane, when it struck New England, was not nearly so serious along the Rhode Island and Connecticut Coast as either the September 1938 or August 1954 hurricanes because (1) its energy had been partly dissipated over the land north of Cape Hatteras, and (2) it struck near the time of a low tide.

In deriving the design hurricane, the 1944 storm was transposed so that it would be over water between Cape Hatteras and the New England coast, resulting in less rise in barometric pressure at the center of the storm as it moved northward than was actually experienced in 1944. The transposed hurricane, having the intensity of the 1944 hurricane off Cape Hatteras, is assumed to move in a due northerly direction with a forward speed of 40 knots (about 46 miles per hour) in one case, and 30 knots (about 35 miles per hour) in a second case, and to pass over New England with its center 49 nautical miles (56 statute miles) west of Montauk Point, Long Island, near the entrance to Long Island Sound. This change in the track of the storm produces the highest surge along the Connecticut coastline, on the north shore of Long Island Sound.

Characteristics of the transposed 1944 storm are approximately the same as a "Standard Project Hurricane" with respect to the central pressure, the radius of the hurricane, storm speed and wind field.

38. DESIGN FLOOD LEVELS

The September 1938 hurricane surge near the eastern entrance to Long Island Sound at the mouth of the Pawcatuck River near Watch Hill, Rhode Island, has been calculated to be 9.5 feet. The surge for the design hurricane has been determined to be 13.4 feet, or 1.4 times greater than the September 1938 surge. The computations of these storm-tide potentials were performed by the Agricultural and Mechanical College of Texas, under contract with the Beach Erosion Board, in connection with their research program.

The design hurricane tidal surge at Pawcatuck was obtained by adding to the 13.4-foot surge at the mouth, the backwater effect of the river, calculated to be 0.8 feet. This storm-tide potential occurring in conjunction with a high spring tide of 2.5 feet at the mouth of the Pawcatuck River would result in a design stillwater level of 16.7 feet, m.s.l. A detailed discussion of the design storm-tide derivation is contained in Appendix B.

39. DESIGN RAINFALL

Records of precipitation are not available in the immediate vicinity of Pawcatuck that would indicate the intensity or total storm rainfall that has occurred during any of the recent hurricanes or major storms. In the 3-4 November 1927 storm, however, Westerly, Rhode Island (across the river from Pawcatuck) had rainfall of 3.15 inches in 4 hours and 15 minutes plus an additional 5.97 inches in the following 8 hours, or 9.12 inches in about 12 hours. The design rainfall criteria for Pawcatuck was based on data contained in the U. S. Department of Agriculture Publication No. 204, "Rainfall Intensity-Frequency Data", which gave an intensity of about 3.5 inches per hour for the local protection project.

40. DESIGN RUNOFF

Design runoff for the Pawcatuck area was determined from the rainfall intensity as discussed in paragraph 39 above, and was the basis of runoff studies for the Pawcatuck area. It was determined that the peak runoff from the area would be 68 c.f.s. In addition, it was estimated that 10 c.f.s. would be contributed from the residential area west of the New York, New Haven and Hartford Railroad.

EXTENT AND CHARACTER OF FLOODED AREA

41. Large areas in Pawcatuck, Connecticut, and Westerly, Rhode Island, are vulnerable to tidal flooding in the 5-mile tidewater reach, at the mouth of the Pawcatuck River and along the adjoining coastal areas fronting on Little Narragansett Bay. Three areas are particularly prone to flooding: (1) the industrial-commercial section of Pawcatuck extending about 0.5 mile downstream from the New York, New Haven and Hartford Railroad bridge, (2) the industrial-commercial section of Westerly extending about 0.5 mile on either side of the railroad bridge, and (3) the Avondale and Watch Hill summer resort sections on Pawcatuck River and Little Narragansett Bay. In the first area, the congested Pawcatuck area near the head of tidewater, nearly 35 dwellings and 50 commercial establishments are susceptible to tidal flooding. This reach includes nearly all of the Pawcatuck commercial establishments and the two largest of the five industrial plants in the village. On the opposite bank, although nearly 60 commercial establishments are subject to tidal flooding in the Westerly urban area, the distribution of these properties is less concentrated. Three industrial firms, employing about 8 percent of Westerly's industrial workers, and approximately one-third of the commercial establishments are exposed to tidal flooding in the Westerly urban area. Nearly one-half of the flood-prone residential and commercial structures in the Avondale-Watch Hill reach are associated with the summer vacation industry. Five

of the six boatyards and yacht clubs in the Pawcatuck River area are located in this Westerly reach and are used primarily for servicing recreational boats based in the numerous coves near the mouth of the river.

HURRICANE TIDAL-FLOOD DAMAGE

42. EXPERIENCED TIDAL-FLOOD LOSSES

Damage surveys conducted in the Pawcatuck River area in late 1956 indicated that damage caused by the tidal flooding which accompanied Hurricane "Carol" on 31 August 1954 amounted to over \$1,900,000. Nearly 50 percent of the total loss in the area occurred in two industrial plants in the Mechanic Street section of Pawcatuck. Beach properties along the Westerly side of the Pawcatuck River sustained nearly one-fourth of the total loss in the area. Most of the remaining loss was experienced by residential and commercial properties in the Pawcatuck-Westerly urban concentration near the head of tidewater. Tidal-flood losses are discussed in detail in Appendix C. Distribution of the total loss by towns and by types of damage is shown in Table 3.

Damages sustained by recreational craft afloat and by transient automobiles in the flooded area accounted for losses which were not included in the tabulations of damages, as specific information on these losses was meager. Available information indicates that losses of this nature were substantial in both the 1938 and 1954 hurricanes.

TABLE 3

EXPERIENCED TIDAL-FLOOD LOSSES
HURRICANE "CAROL", 31 AUGUST 1954
PAWCATUCK, CONNECTICUT, AND WESTERLY, RHODE ISLAND

(Losses in \$1,000)

<u>Town</u>	<u>Urban</u>	<u>Rural</u>	<u>Industrial</u>	<u>Utility</u>	<u>Highway</u>	<u>Total</u>
Pawcatuck	255	5	820	5	5	1,090
Westerly	750	--	20	25	25	820
	1,005	5	840	30	30	1,910

43. RECURRING TIDAL-FLOOD LOSSES

On the basis of stage-loss data obtained from field investigation of damages, estimates have been made of the recurring losses that would be experienced in future hurricanes at the various stages above and below the 1954 flood level. These losses are summarized in Table 4, below. Additional data on the determination of recurring losses and a breakdown of anticipated recurring losses in the Pawcatuck industrial area are included in Appendix C.

TABLE 4

RECURRING TIDAL-FLOOD LOSSES IN PAWCATUCK RIVER AREA
(1958 Price Level)

Pawcatuck (Stonington), Connecticut and Westerly, Rhode Island

<u>Recurring Hurricane</u>	<u>Flood Stage</u> (feet, m.s.l.)	<u>Recurring Losses</u>
21 Sept. 1938	11.1	\$2,600,000
31 Aug. 1954	10.4	1,900,000
14 Sept. 1944	7.6	200,000

44. AVERAGE ANNUAL FLOOD LOSSES

Average annual flood losses in the industrialized Mechanic Street area in Pawcatuck, as determined from damage-frequency relationships, are estimated at \$67,000.

45. SCARE COSTS

In addition to tidal-flood losses, significant costs result from the institution of temporary preventive measures following a hurricane warning even though the anticipated hurricane does not cause flooding. Included among such measures are provisions for sandbagging windows and other openings, installation of pumping facilities, and plans for temporary evacuation of space, machinery and other equipment likely to be flooded. It is estimated that "scare costs" to industrial interests in the Mechanic Street section of Pawcatuck will amount to \$6,000 in each hurricane scare. Based on a frequency of four warnings every ten years, a frequency consistent with past records in this area and adjacent coastal areas, average annual scare costs for the Mechanic Street industrial area amount to \$2,400.

EXISTING CORPS OF ENGINEERS' PROJECTS

46. HURRICANE PROTECTION PROJECT

There is no existing or authorized Corps of Engineers' hurricane protection project for the prevention of hurricane tidal-flood damages in the Pawcatuck area.

47. NAVIGATION PROJECTS

Federal improvement of Pawcatuck River and Harbor in the interest of navigation dates back to 1871. The existing project, adopted in 1896, provides for a channel 10 feet deep and 200 feet wide in Little Narragansett Bay and the River from Stonington to Avondale, thence 100 feet wide to the lower wharves at Westerly; thence 40 feet wide to the upper wharves, length about 7.5 miles; a channel 10 feet deep, 100 feet wide from the mouth of the river into Watch Hill Cove, length about 0.28 mile; an anchorage basin 10 feet deep in Watch Hill Cove; a riprap groin near southwest corner of the basin, about 200 feet long; and removal of obstructions at Watch Hill. The existing project is 71% completed.

HURRICANE PROTECTION IMPROVEMENTS BY OTHERS

48. FEDERAL AND STATE IMPROVEMENTS

No improvements in the interest of minimizing hurricane tidal-flood damages in the Pawcatuck area have been undertaken by any other Federal agencies or by the State of Connecticut.

IMPROVEMENTS DESIRED

49. PROPOSALS BY LOCAL INTERESTS

Officials of Stonington, Connecticut, and Westerly, Rhode Island requested high priority for studies of protection of the heavy damage areas near the Pawcatuck River and proposed two alternative plans of protection:

a. Closing the breach in Sandy Point and raising Sandy Point and Napatree Point above flood level to form a barrier that would protect the Little Narragansett Bay and Pawcatuck River area.

b. Construction of a rock barrier with navigation opening across the Pawcatuck River at Pawcatuck Rock to prevent the tidal surge moving up the river.

Local interests stressed the urgency of protection for their industrial and commercial center as one of the larger manufacturers had moved out of the area in 1958.

50. MEETING WITH LOCAL INTERESTS

During the course of the survey, several meetings were held with representatives of both State and local governments as well as local industrial interests, to inform them of the progress of the survey, and to obtain their views on the various plans of protection being considered. They insisted that if no economical plan of hurricane protection could be provided for the area as a whole, that every consideration be given to protecting the industrial area on the west bank of the Pawcatuck River.

51. PUBLIC HEARING

A public hearing was held in Stonington, Connecticut on 20 February 1958, to acquaint local interests with the results of the survey and to determine their views and opinion on a plan of local protection for the industrial area on the west bank of the Pawcatuck River. The meeting was attended by about 50 persons including State and local officials, representatives of local industrial and commercial interests, and home owners. At this meeting, local interests restated their need for protection and expressed unanimous approval of the plan of local protection for the Pawcatuck industrial area. State and local interests indicated a willingness to share in the cost of the project.

TIDAL-FLOOD PROBLEM AND SOLUTIONS CONSIDERED

52. TIDAL-FLOOD DAMAGES

Hurricane damages result chiefly from (1) salt-water flooding by the hurricane surge, (2) action of storm-driven waves, (3) fresh-water flooding resulting from torrential rains, and (4) effect of high-velocity winds. This report involves mainly the damages arising from salt-water tidal flooding. Damages from wave action occur in the more exposed coastal areas and are minor in the Pawcatuck River. Fresh-water runoff and flood damages are of secondary importance in the Pawcatuck areas that are subject to tidal flooding. Wind damages are not included in this study.

Damages caused by hurricanes and other great storms may take many forms, including loss of life and property, hazards to health, disruption of normal economic activities, costs of evacuation and reoccupation, and abandonment of industrial and commercial

activities in the area. Some types of damage cannot be prevented, although they may be relieved by careful planning. Damages resulting from tidal flooding of coastal areas or estuaries and fresh-water flooding of river valleys can be significantly reduced in some cases by adequate protective structures.

53. HURRICANE FLOOD PROBLEM

The engineering problem of hurricane tidal flood protection in the Pawcatuck area resolves itself into one of providing protection for as much of the flood area as is economically feasible and practicable. Flooding in this area is caused by the hurricane surge which comes over the top of the barrier beaches (Napatree Beach and Sandy Point), flows through the navigation passage near Stonington, and through the breach in Sandy Point opened by the 1938 hurricane. The surge rises in Little Narragansett Bay and flows up the Pawcatuck River to the concentrated damage areas. The damages have been caused by salt water brought in from the sea by hurricane-induced tidal surges and other great storms. Fresh-water flooding from 295 square miles of watershed has not in the past caused major flood damage at Pawcatuck, but has increased flood levels during periods of salt-water flooding.

In the Pawcatuck River and Little Narragansett Bay area of Westerly, Rhode Island, and Stonington, Connecticut, damages of more than \$1,900,000 were sustained from Hurricane "Carol", 31 August 1954. A major part of these damages, nearly 50 percent, were experienced by industry about five miles up the river on the Connecticut bank. Except for this concentration, the damages were widely dispersed on the banks of the river and along the shoreline of Little Narragansett Bay.

54. DEGREE OF PROTECTION REQUIRED

The degree of required protection is indicated by the fact that the area experienced tidal flooding to an elevation of 11.1 feet above mean sea level in the hurricane of 21 September 1938, and to an elevation of 10.4 feet above mean sea level in Hurricane "Carol", 31 August 1954. Some of the industrial buildings were inundated to depths ranging to 5.8 feet above the first floor level. In the event of a Standard Project Hurricane occurring coincident with the peak of a high spring tide, the waters of the lower reaches of the Pawcatuck River would rise to an estimated height of 16.7 feet above mean sea level, and 5.6 feet above the 1938 flood level.

55. PROTECTIVE MEASURES CONSIDERED

Protective measures fall into the following classifications: (a) hurricane warning and emergency flood mobilization measures, including plans for evacuation; (b) revision of zoning regulations and building codes; and (c) protective structures such as dikes, walls, breakwaters, bulkheads and local tidal barriers designed to protect individual portions of the shorefront subject to tidal flooding. These measures are described below:

a. Hurricane warning and emergency flood mobilization measures. A hurricane warning system, combined with emergency mobilization and plans for evacuation, would materially aid in preventing loss of life and property. Such a system, however, would not alleviate the problem of physical inundation of properties. Considerable time is required for emergency precautionary measures, such as boarding up and sandbagging windows, evacuating low-lying areas, removing goods and equipment to higher levels, pulling small craft ashore, and driving vehicles to high ground. A warning system, no matter how extensive and elaborate, might not always provide sufficient time for adequate precautions. The hurricane of 1938, for example, which was at one time reported stalled off Cape Hatteras, swept north to the New England coast, almost unannounced, only eight hours later.

Hurricane alerts and near misses, that result in "scares" only, interfere with the normal activities of the affected residents and in many cases may cause economic loss. It is reported that a single hurricane "scare" incurs costs of \$6,000 in Pawcatuck. The hurricane warning services now provided by the U. S. Weather Bureau are necessary, however, to supplement any plan of protection for the Pawcatuck area.

b. Revision of zoning regulations and building codes. The consideration of warnings and emergency measures leads to thought of more permanent relocation of goods and equipment to higher floor levels, relocation out of the flood area entirely, or of more substantial construction to resist the destructive forces of high water and waves. State and local governments, in some instances, have proposed adoption of zoning restrictions to prevent new construction in critical flood areas and revisions of building codes to require sturdier construction in areas where buildings have been demolished by storm tides. Such measures, where proposed for existing concentrations of homes, commercial establishments, and industries, tend to meet with strong opposition because of the high investment in property and the prospective loss to property owners and municipalities. The responsibility for enacting legislation on zoning and building regulations lies with the State and municipalities concerned.

c. Protective structures. Although hurricane warnings, mobilization measures, and revised zoning regulations and building codes will abate the danger of flood damages, they will not eliminate the inherent danger from tidal flooding. The most positive means of protection is by construction that will physically reduce or prevent the inundation of properties by tidal-flood waters that enter the Pawcatuck River at the time of a hurricane. Considered structures include barriers which would completely or partially close off the waterway to the entry of hurricane tides; dikes or walls along the shore which would hold back the high water and give local protection; or a combination of barriers, dikes, and walls. The construction of breakwaters would effect a reduction in hurricane wave heights in more exposed areas. Wave damage, however, is a negligible factor in the damage at Pawcatuck.

56. PLANS CONSIDERED

Consideration has been given to several plans of protection throughout the Pawcatuck-Little Narragansett Bay area, as follows:

a. Use of Natural Barrier Beaches. Hurricane protection by this plan would consist of a barrier-dike system, approximately four miles in length, extending from Watch Hill along Napatree Point and Sandy Point to Stonington. Consideration was given to both gated and ungated navigation openings at the navigation channel north of Sandy Point. This plan would give general protection to the whole of Little Narragansett Bay and the navigable reaches of the Pawcatuck River.

b. River Crossings. Sites for barriers, crossing the Pawcatuck River, were investigated at Pawcatuck Rock and at several alternative locations along the river south of the town. Plans studied varied in respect to methods of providing navigation openings through the barriers, and in methods for the prevention of fresh water ponding behind the barriers. Ponding would be controlled either by a large pumping station or by a diversion channel west of Pawcatuck. These plans would provide protection for much of the Pawcatuck-Westerly area.

c. Local Protection. Local protection by dikes or walls was investigated for concentrated damage areas in Pawcatuck and Westerly.

57. SELECTION OF PLAN OF PROTECTION

The following points were taken into account in eliminating a number of plans for general protection early in the survey and

arriving at the selection of the Pawcatuck local protection plan for further study.

a. The general protection of Little Narragansett Bay would involve a barrier along Napatree Beach and Sandy Point. The extensive length of such a system would mean a high construction cost. In addition, hydraulic studies indicate that the barrier would require a large navigation opening in order to avoid excessive tidal currents under normal conditions. It was determined that, because of the high cost of such a barrier and navigation gate, the utilization of the barrier beaches for the general protection of Little Narragansett Bay would not be economical or feasible.

b. Barriers across the Pawcatuck River in the vicinity of Pawcatuck Rock to give complete protection to the estuary above the barrier were investigated at some length. Due to the lack of storage area, ponding would occur behind such a barrier, causing fresh water flooding from 300 square miles of drainage area. A pumping station with sufficient capacity to pass the storm water runoff of the river basin, would be prohibitive in cost. A diversion plan, to bypass the storm water runoff of the river past Pawcatuck, was also eliminated by its high cost. Hydraulic studies showed that a gated opening would be required in a barrier crossing the river because the ponding area is small.

c. Utilization of barrier beaches and river crossings alike were determined to be more costly than the benefits would justify. Thus no general or over-all protection plan of the area proved to be feasible.

d. Local protection of small areas characterized by a concentration of experienced flood damages emerged as the only answer to the problem. This eliminated all consideration of navigation gates and large pumping stations for river flow, although pumping on a smaller scale for local drainage might still be necessary.

e. An examination of possibilities for local protection projects disclosed that the industrial section in Pawcatuck suffered the heaviest concentration of damages from recent hurricanes of record, nearly 50 percent of the total. This area appeared to lend itself to a simple and practicable means of protection.

HURRICANE FLOOD CONTROL PLAN

58. The analyses of various alternate plans indicated that local protection of the industrial section of Pawcatuck is the most promising project in the survey area.

59. PAWCATUCK LOCAL PROTECTION PLAN

The Pawcatuck local protection project is shown on Plate 2 of this report. The main feature of the plan is a dike and land wall system extending about 2,000 feet along the west bank of the Pawcatuck River. More detailed material is contained in Appendix E.

This protection consists of 2,386 linear feet of earth-fill dike, 208 linear feet of concrete wall and a pumping station. The dike would be rock faced on the top and river slope, with a gravel blanket on the landward slope. The protection begins at high ground south of the Cottrell plant, extends along the water front to the north boundary of the Bostitch plant and then ties into the railroad embankment west of Mechanic Street. The dike portion would have a top elevation of 17.0 feet above mean sea level, a top width of 10 feet, and side slopes of 1 on 2 both sides. The wall forming the northern end of the protective works would have a top elevation of 17.0 feet above mean sea level.

Appurtenant structures consist of a 40,000 g.p.m. pumping station located on the grounds of the Cottrell plant and two stop-log structures, crossing Mechanic Street, one located at the railroad underpass south of the Cottrell plant and the other in the protective alignment north of the Bostitch plant.

60. DRAINAGE MODIFICATIONS

Construction of the proposed plan of protection would cross many of the existing drains and sewers, throughout the area behind the protective works, thus necessitating the construction of an interceptor sewer along the toe of the dike. The interceptor would carry all sewage, interior runoff and industrial wastes to an inlet chamber in the pumping station. At this point the flow would be directed, by means of sluice gates, to pass through the pumping station during times of flooding and through a 48 inch outfall directly to the river during normal conditions.

61. LANDS, RIGHTS-OF-WAY AND RELOCATIONS

Construction of the project would require the acquisition in fee of about 2.7 acres of land and a temporary construction easement on one acre of land. Land within easement areas not actually occupied by protective structures and all permanent access roads would be available for use by the owner.

62. HYDROLOGIC AND HYDRAULIC CONSIDERATIONS

The design of the Pawcatuck local protection project was based on the following:

a. A design stillwater level of 16.7 feet above mean sea level, derived from tidal surge determination predicated on wind fields and barometric pressures of a hurricane on a northerly track passing 49 nautical miles west of Montauk Point with the peak of the surge coincident with a high spring tide plus allowance for a differential in the water level at the coastline and the level upstream at the project.

b. A maximum rainfall intensity of approximately 3.5 inches per hour over the 39-acre project area, based on the U. S. Department of Agriculture Rainfall Intensity - Frequency Data.

c. Design runoff, obtained from the Rational Formula ($Q=CIA$), with a peak of 68 c.f.s. from the protected area plus an estimated 10 c.f.s. from the area above the New York, New Haven and Hartford Railroad embankment.

d. A pumping station with a capacity of 89 c.f.s. (40,000 g.p.m.).

63. DEGREE OF PROTECTION

The Pawcatuck local protection project would afford complete tidal-flood protection to about 31 acres of property in Pawcatuck below an elevation of 16.7 feet, m.s.l. This represents protection to an area in which nearly 50 percent of the total flood damages were sustained although geographically it covers about 2 percent of the entire flooded area.

64. EFFECT OF PLAN ON HARBOR INTERESTS

The effects of the Pawcatuck local protection project on the various interests concerned with the use of the river and waterfront areas at Pawcatuck are discussed in the following paragraphs:

a. Navigation. The selected plan of protection will have no effect on the range of tide, nor will there be any reduction in the depth of water available for navigation.

b. Pollution. Federal and State health authorities have considered the effect of the protective system on pollution in the Pawcatuck River. They have concluded that the plan will not adversely affect sanitary conditions in the river.

c. Fish and Wildlife. Federal and State fish and wildlife interests have concurred in the opinion that the selected plan of protection will not be detrimental to the fishing resources of the area.

d. Recreation. The selected plan of protection will have no adverse effect on the present recreational activities of the area.

e. Industry. The plan will not require the removal of any commercial or industrial buildings or cause curtailment of present industrial activities. Much of the project benefits would accrue to industry.

65. EFFECT OF PLAN ON ADJACENT SHORELINE

The dikes in the selected plan of hurricane protection for Pawcatuck will not cause accretion or erosion along the adjacent shoreline.

ESTIMATES OF FIRST COST

66. All estimates have been prepared on the basis of 1958 price levels, using unit prices based on actual bid prices of similar work in the region. The estimated total first cost is \$585,000 which includes allowances for engineering and design and for supervision and inspection during construction. Table 5 summarizes the principal items of first cost with detailed costs given in Appendix E. The figures in the tabulation are based on local interests contributing 30 percent of the first cost of the project. The contribution to the first costs comprises (1) a cash contribution presently estimated at \$86,000, and (2) furnishing all required lands, easements, rights-of-way and relocations, presently estimated at \$90,000.

ESTIMATES OF ANNUAL CHARGES

67. Total annual charges amount to \$27,000, and include interest at a rate of 2.5 percent, amortization over a 50-year project life, and an allowance of \$5,800 for annual operation and maintenance, which includes a charge to cover the cost of major replacements during the estimated life of the project. Local interests would be required to maintain and operate the project.

TABLE 5

FIRST COSTS AND ANNUAL CHARGES
(1958 Price Level)
PAWCATUCK LOCAL PROTECTION PLAN
PAWCATUCK, CONNECTICUT

<u>Item</u>	<u>Federal</u>	<u>Local</u>	<u>Total</u>
<u>First Cost and Investment</u>			
Construction of Dike, Land Wall and Pumping Station	\$409,000	\$86,000(1)	\$495,000
Relocation of Gas and Water Utilities	--	10,000	10,000
Lands and Damages	--	80,000	80,000
Subtotal - First Cost	\$409,000	\$176,000	\$585,000
Preauthorization Survey Studies	10,000		10,000
Interest during construction	5,000	2,000	7,000
Total Investment Cost	\$424,000	\$178,000	\$602,000
<u>ANNUAL CHARGES</u>			
Interest on Investment	\$ 11,000	\$ 4,000	\$ 15 000
Amortization	4,000	2,000	6,000
Maintenance and Operation	--	5,800(2)	5,800 (2)
Estimated Tax Losses	--	200	200
Total Annual Charges	\$ 15,000	\$ 12,000	\$ 27,000

(1) Represents a local cash contribution, presently estimated at \$86,000, to the United States. This amount, when added to the estimated cost of \$90,000 for lands, easements, rights-of-way and relocations necessary for the construction of the project, represents a local interests share of 30 percent of the first cost of the project.

(2) Includes estimated cost of major replacements.

ESTIMATES OF BENEFITS

68. TANGIBLE BENEFITS

Evaluated benefits for the Pawcatuck local protection plan include average annual flood damages prevented by the plan and benefits from the elimination of scare costs in the protected area. Total average annual flood damage prevention benefits are estimated at \$55,000, at 1958 prices. Approximately 3 percent of this amount could be credited to fresh-water flood prevention benefits. This amount equals the difference between the average annual losses in the Pawcatuck industrial area before protection and the residual average annual losses after addition of protective works.

Average annual benefits from the elimination of scare costs amount to \$2,400. Thus the total average annual benefits accruing to the plan are \$57,400.

69. UNEVALUATED TANGIBLE BENEFITS

In view of the small area encompassed by the protection plan and the high degree of industrial and residential development within the area, no significant enhancement benefits are anticipated in the protected area. Since the 1954 flood, the Bostitch Corporation, the more northerly of the two large industrial firms in the protected area, has moved to a larger plant outside the Pawcatuck area. It is anticipated that their well designed, up-to-date Pawcatuck plant will be reoccupied by industrial tenants irrespective of protective works. As the primary factor influencing relocation of the Bostitch firm in 1957 was the need for additional space, rather than an endeavor to avoid flood costs, the benefits accruing from protection of their Pawcatuck plant have been computed as flood damage prevention benefits based on the normal industrial reoccupancy of the plant.

70. INTANGIBLE BENEFITS

Construction of adequate protective works in the Mechanic Street section of Pawcatuck would greatly reduce the threat to life and the danger of disease from polluted flood waters in this industrial-residential area. Insecurity and worry among the residents concerning unpredictable hurricane flooding would be virtually eliminated.

ECONOMIC JUSTIFICATION

71. BENEFIT-COST COMPARISON

A comparison of annual charges of \$27,000 with annual benefits of \$57,400 determined from damage-frequency relationships, gives a benefit-cost ratio of 2.1 to 1.0 for the selected plan of protection. The prevention of damage in one recurrence of a great hurricane would alone be more than sufficient to economically justify the construction of the project.

PROPOSED LOCAL COOPERATION

72. The hurricane protection plan considered for Pawcatuck, Town of Stonington, Connecticut, is a project for local protection against hurricane-induced tidal flooding. On this basis, local interests would be required to participate as follows:

a. Contribute 30 percent of the first cost of the project (not including the cost of preauthorization survey studies) as follows:

(1) Make a cash contribution presently estimated at \$86,000.

(2) Provide without cost to the United States all lands, easements, rights-of-way and relocations necessary for construction of the project, presently estimated at \$90,000.

b. Hold and save the United States free from damages due to the construction works.

c. Maintain and operate all the works after completion in accordance with regulations prescribed by the Secretary of the Army.

At the public hearing held 20 February 1958, local interests voiced a willingness to participate in project costs, as well as maintenance and operation, in accordance with policies governing flood control projects. Subsequent to the hearing, statements on willingness to comply with a(2), b and c of the above provisions of local cooperation have been received from the Governor of Connecticut and responsible elected officials of the State of Connecticut and Town of Stonington. The Town of Stonington has expressed an ability and willingness to participate with the State in compliance with a(1) above. The State has indicated probable cooperation in the contribution required of local interests, although the extent of the contribution by the State is dependent on the outcome of the January 1959 session of the State legislature. See Appendix F for more detailed information on the hearing.

APPORTIONMENT OF COSTS AMONG INTERESTS

73. A breakdown of the total first cost and annual charges for the Pawcatuck local protection project, between Federal and non-Federal interests, is shown in Table 5. The figures in this table are predicated on local cooperation to the extent set forth in paragraphs 66 and 72, above, with local interests making a cash contribution to the first cost of the project.

The first cost of the project is estimated at \$585,000. The first cost to local interests is presently estimated at \$176,000, including \$90,000 for the acquisition of lands, rights-of-way, relocations, and a cash contribution of \$86,000. The Federal first cost is presently estimated at \$409,000 exclusive of \$10,000 for pre-authorization survey studies.

The total annual charges for the project are estimated at \$27,000. The Federal portion is \$15,000 and the local share \$12,000 or about 44 percent of the total.

COORDINATION WITH OTHER AGENCIES

74. In the course of this survey, assistance and cooperation have been received from Federal, State, and local agencies that are concerned with hurricane activities, or are particularly interested in the hurricane protection problem in Pawcatuck. Meetings have been held with representatives of these agencies for the purposes of discussing the proposed plan of protection and alternative plans, determining the effect of the plan on other interests concerned with development and use of the water and other natural resources of the locality. These meetings have also developed the relationship between the proposed hurricane protection plan and the plans of other agencies for improvements within the survey area.

a. Federal agencies. The U.S. Weather Bureau of the Department of Commerce has furnished information on the behavior and characteristics of past hurricanes and data on maximum wind velocities and durations that may be expected in future storms.

The Fish and Wildlife Service of the U.S. Department of the Interior, and the Public Health Service of the U.S. Department of Health, Education and Welfare have considered the dike and land wall plan and state that it would have no adverse effect on fishing resources and sanitary conditions in the area.

b. State agencies. The effect of the proposed dike and land wall on pollution has been discussed with the Connecticut State Water Resources Commission. This commission concurs in the opinion that the hurricane protection plan will have no adverse effect on

sanitary conditions in the area. Coordination also has been maintained with the Commission with a view to determining the needs of navigation and correlating the plan of protection with these needs. The Connecticut State Board of Fisheries and Game has considered the barrier plan and state that it would have no adverse effect on the fishing resources of the area.

c. Local agencies. Informal meetings and conferences have been held with municipal officials of Pawcatuck and representatives of industrial interests to obtain their views and comments on the proposed plan and other plans that have been given consideration and to keep local interests advised of the progress being made on the survey.

DISCUSSION

75. THE PROBLEM

The Pawcatuck River and Little Narragansett Bay areas have experienced heavy losses of life and property; over 100 people were drowned in the 1938 hurricane and over 250 homes and buildings swept away. The buildings were not rebuilt on the Napatree Point outer barrier beach. In future hurricanes flood losses are likely to be less in amount and distributed over wide areas except at Pawcatuck, Connecticut where \$1,290,000, about 50% of the total estimated damage for a recurring 1938 hurricane, would be concentrated in a small industrial and residential area, five miles up the Pawcatuck River. A design hurricane representative of future potential attacks, derived by transposing the 1944 hurricane, a storm of unusual energy off Cape Hatteras, to a track over water and timed to cause the surge to strike coincident with a spring tide, is capable of causing tidal flooding approximately six feet higher than the 1954 hurricane at Pawcatuck. Protection of this area is needed to sustain the economy and normal employment in the area.

76. ALTERNATIVE SOLUTIONS

Some reduction in hurricane tidal-flood damages could be effected in the Pawcatuck-Little Narragansett Bay area by the institution of improved forecasting and warning services, the establishment of programs for the evacuation of danger areas, the enactment of revised zoning ordinances, and the adoption of modified building codes. Improved warning facilities and plans for evacuation would be desirable for the whole area, as effective in reducing the loss of life and damage to items which are readily movable. However, such emergency measures do not prevent the actual flooding of properties and would therefore be of limited value in preventing damage, particularly in the industrial area of Pawcatuck. The costs incurred by relocation of buildings and rezoning of areas subject to tidal flooding would be prohibitive

in this highly developed area. The valuation of property involved is many times the cost of protection or the amount of damages. Moreover, any extensive relocation would disrupt the entire economy of the area. A positive means of protection which will eliminate the threat of future flooding to existing properties is desirable, particularly in the Pawcatuck industrial section.

77. SELECTION OF PLAN

Plans of protection were considered for the whole Pawcatuck-Little Narragansett Bay area by raising the outer barrier beaches but they proved too costly. Intermediate plans consisting of barriers across the Pawcatuck River, proved to be impractical because of the large fresh-water flow from the 300 square mile Pawcatuck River watershed. Local protection was considered for several areas but the only plan found to be practical and economically feasible is local protection for the principal industrial area of Pawcatuck. Although this plan would provide protection for approximately 2 percent of the flooded area it would prevent about 50 percent of the losses. The plan provides for a dike and land wall system tying into high ground north and south of the industrial properties, and would afford complete protection from flooding for two large industrial plants and 27 residences. These works, with a top elevation at 17.0 feet, m.s.l. are designed to afford protection to a stillwater flood level of 16.7 feet, m.s.l. This design flood level is 5.6 feet above the elevation of flooding experienced in the record hurricane of September 1938.

78. EFFECTS ON OTHER INTERESTS

The proposed project would have no adverse effects on pollution or on fish and wildlife. Construction of the dike would not change the tidal range, or affect navigation in the Pawcatuck River.

79. COSTS

The first cost of the project, including lands, rights-of-way and relocations is estimated at \$585,000. The annual charges are estimated at \$27,000.

80. BENEFITS

The average annual benefits to be obtained from the protection provided by the Pawcatuck local protection project are estimated to be \$57,400. This includes \$55,000 derived from the elimination of flood damages, and \$2,400 from the elimination of scare costs. The benefit-cost ratio of the project is 2.1 to 1.0.

CONCLUSIONS

81. It is concluded that Pawcatuck, Town of Stonington, Connecticut, has sustained heavy damages in the past due to flooding caused by hurricanes and other great storms; and that this area faces the continuing threat of similar damages in the future. It is further concluded that protection against tidal flooding can be attained most suitably through the construction of a dike-land wall system at the principal industrial area of Pawcatuck at a first cost of \$585,000. This plan, which would afford a high degree of protection, is amply justified, having a benefit-cost ratio of 2.1 to 1.0.

RECOMMENDATIONS

82. It is recommended that a plan of local protection against hurricane floods be authorized for Pawcatuck, Connecticut as described in paragraph 59 of this report, consisting of a dike and accessory works. The presently estimated first cost of the project is \$585,000 to be borne jointly by the United States and local interests. The estimated first cost to the United States is \$409,000.

It is further recommended that the project be authorized subject to the condition that local interests cooperate to the following extent:

a. Provide without cost to the United States all lands, easements, and rights-of-way necessary for the construction of the project.

b. Hold and save the United States free from damages due to the construction works.

c. Accomplish without cost to the United States all relocations of and modifications to the existing storm-drainage system, and utilities made necessary by reason of construction of the project; the costs incurred to be credited to the required local cash contribution to the project first cost.

d. Operate and maintain all the works after completion in accordance with regulations prescribed by the Secretary of the Army.

e. Contribute in cash an amount, presently estimated at \$86,000, equal to 30 percent of the first cost with credit allowed for the costs incurred in fulfilling local cooperation requirements a and c above.

ALDEN K. SIBLEY
Brigadier General, U.S. Army
Division Engineer

PUBLIC HEARING AND VIEWS OF OTHER AGENCIES

LETTER FROM THE BOARD OF FISHERIES AND GAME,
STATE OF CONNECTICUT



STATE OF CONNECTICUT

BOARD OF FISHERIES AND GAME

2 WETHERSFIELD AVENUE • HARTFORD, CONNECTICUT

ADDRESS ALL MAIL TO
STATE OFFICE BUILDING, HARTFORD

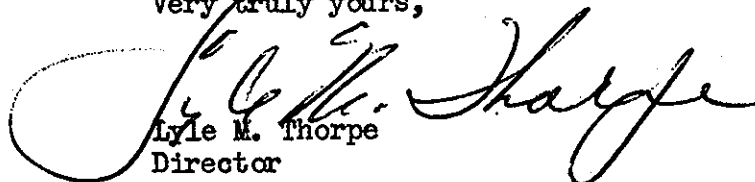
June 2, 1958

Lt. Col. Miles L. Wachendorf
Army Engineer Division, New England
Corps of Engineers
150 Causeway St.
Boston 14, Mass.

Dear Col. Wachendorf:

Reference is made to your letter of May 19th announcing studies to determine the possibility of providing hurricane protection in Pawcatuck, Connecticut. We have carefully studied the plan under study which you kindly provided us and we believe that these would not be detrimental to the wildlife interest; therefore, we approve the plans as submitted and have no suggestions for any changes.

Very truly yours,


Lyle M. Thorpe
Director

LETTER FROM DEVELOPMENT COMMISSION, STATE OF CONNECTICUT



STATE OF CONNECTICUT
DEVELOPMENT COMMISSION
STATE OFFICE BUILDING • HARTFORD 15, CONNECTICUT

February 21, 1958

Brigadier General Alden K. Sibley
Division Engineer
U. S. Army Engineers, New England Division
Corps of Engineers
150 Causeway Street
Boston 14, Massachusetts

Dear General Sibley:

Relative to the hearing which was held on February 20 at Stonington, Connecticut concerning the building of dikes at the Cottrell and Bostitch plants in Pawcatuck, Connecticut, this Commission does recommend that favorable consideration be given to do this particular project.

Currently the employment situation in much of this state is such that the state and federal governments should do everything possible to protect present and future manufacturing operations along the shoreline.

The Bostitch property and area is one that has an excellent potential for employing manufacturing workers in both Connecticut and Rhode Island and thus deserves particular attention at this time.

I hope you will render favorable consideration of this recommendation.

Sincerely yours,

A handwritten signature in cursive script that reads "LeRoy Jones".

LeRoy Jones
Asst. Managing Director

LETTER FROM THE GOVERNOR OF CONNECTICUT

ABRAHAM RIBICOFF
GOVERNOR



STATE OF CONNECTICUT
EXECUTIVE CHAMBERS
HARTFORD

August 26, 1958

Brigadier General Alden K. Sibley
New England Division Engineer
Corps of Engineers, U. S. Army
150 Causeway Street
Boston 14, Massachusetts

Dear General Sibley:

This will refer to your letter of August 22 requesting opinion concerning the report on hurricane tidal-flood protection at Pawcatuck, Connecticut.

I have consistently supported sound programs for the protection of the people of Connecticut and their development against damages from floods and hurricanes. The Stonington area has suffered heavy damage from tidal flooding during past hurricanes and protection against the recurrence of such damages is needed.

At the present time there are no specific State funds available for participating in such projects in accordance with the requirements as contained in your letter. However, the executive, legislative and administrative agencies of the State have cooperated and participated in sound projects in the past and now there is no reason to assume that the same policies will not be followed in a sound program for the protection of the Stonington area when such a project reaches the stage of construction.

Sincerely,

Abraham Ribicoff
Governor

LETTER FROM THE HONORABLE DAVID M. JOHNSTONE, SENATOR,
20TH DISTRICT



CONNECTICUT STATE SENATE
HARTFORD

SENATOR DAVID M. JOHNSTONE
Twentieth District

COMMITTEES

Elections, Chairman
Fish and Game
Water Resources and Flood Control
Public Health and Safety

February 19, 1958

U. S. Corps, Army Engineers
150 Causeway Street
Boston, Massachusetts

Gentlemen:

Re: Pawcatuck River Hurricane Protection.

As a member of the State Legislative Water Resources and Flood Control Committee, I am aware of the great interest of the Federal government as represented by the Department of Engineers, in flood control projects.

The 1955 floods in Connecticut and the many proposed flood control projects arising therefrom have demonstrated to us again, your deep interest in flood control even though, as in the case of the 1955 floods, they may only occur once in some fifty years.

We have before us in the Pawcatuck hurricane flood protection project, a project that is certainly as worthy as many of the other flood projects throughout the State. In this particular case, the flooding experience has been on the average of every five years which is considerably more often than many other flood protection projects.

To me, there is no difference between being flooded by salt water than there is by fresh water. However, to date, there has been definite discrimination against those who would be protected against flooding by salt water while there has been a readiness or even an eagerness to protect against fresh water flooding. I believe that we have in this project, an ideal opportunity to demonstrate the worthiness of a salt water flooding protection. It is not an expensive project, but yet has a very high benefit-cost ratio.

As far as a contribution from the State of Connecticut is concerned, I can only speak as one member of the Legislature, but I feel that any contributions to salt water flood protection should be just as generous as those for any other type of flood protection in the State.

Yours very truly,

A handwritten signature in cursive script, reading "David M. Johnstone".

David M. Johnstone
Senator, Twentieth District

LETTER FROM THE FIRST SELECTMAN, TOWN OF STONINGTON,
CONNECTICUT

NATHAN F. CULVER

ALBAN PAMPEL

WILLIAM R. STEWART

Town of Stonington, Conn.

SELECTMEN'S OFFICE, TOWN HALL

Telephone Mystic Jefferson 6-9361

February 19, 1958

U. S. Army Engineers
150 Causeway Street
Boston, Mass.

Gentlemen:

Re: Pawcatuck Hurricane Protection.

I believe that the proposed project for hurricane flood protection in the Pawcatuck River that will involve the Cottrell Company, Bostitch, and a number of private homes is necessary for the safety from flood of the area and that it is economically justified. The project protects the two largest taxpaying and employing industries in the Town. Besides the direct benefit of the dike to the two plants, we have the indirect benefits to the facilities serving the plant as well as the wage earners and all of the services serving them.

Although the exact proportion of the cost of the project between the Federal, State and local interests are not known at this time, I feel it possible to say that local Town interests will contribute to the cost of the project.

It is my understanding that this local interest contribution can be made by those directly effected such as Cottrell's and Bostitch, other private interests in the Town as well as local Town tax money which, of course, would have to be voted at a Town Meeting.

Yours very truly,



David M. Johnstone
First Selectman

LETTER FROM THE FIRST SELECTMAN, TOWN OF STONINGTON,
CONNECTICUT

Town of Stonington, Conn.

SELECTMEN'S OFFICE, TOWN HALL

Telephone Mystic Jefferson 6-9361

September 4, 1958

U. S. Army Engineer Division
150 Causeway Street
Boston 14, Massachusetts

Gentlemen:

Ref. File: NEDGW

I am replying to your letters of August 22 and 26 regarding an opinion about the willingness and ability of local interests to meet the requirements of cooperation for hurricane tidal-flood protection at Pawcatuck and Mystic, both in the Town of Stonington.

The matter was brought up in a recent meeting of the Board of Selectmen and it is its opinion that the Town would be unwilling and unable to meet the entire 30% contribution requested of local interests in both cases. However, it is still the Board's opinion that there is willingness on the part of the Town to bear part of the cost of the project as well as its maintenance.

The exact percentage can't be set at this time, and of course, would have a great deal to do with the contribution on the part of the State of Connecticut which from your point of view is part of the 30% contribution of local interests. The State Legislature has not had a State-aid salt water flood protection program before it, although it is anticipated that the next session in January 1959 will have such a request. As far as the Town of Stonington is concerned, it will have to wait for the outcome of this legislation.

Yours very truly,


David M. Johnstone
First Selectman

LETTER FROM THE CHIEF ENGINEER, WATER RESOURCES COMMISSION,
STATE OF CONNECTICUT



STATE OF CONNECTICUT
WATER RESOURCES COMMISSION
STATE OFFICE BUILDING • HARTFORD 15, CONNECTICUT

February 21, 1958

The Division Engineer
New England Division
150 Causeway Street
Boston 14, Massachusetts

Dear Sir:

Reference is made to your letter of 30 January requesting comments on your proposed hurricane protection plan for the industrial area of Pawcatuck, Connecticut.

This proposed protection plan was presented to the Water Resources Commission at its meeting on February 3, 1958. The Commission, after considerable discussion, voted "approval of the general idea" and directed that a statement to this effect be made at the public hearing. In addition to this comment on the plan in general, you request comment on the possible participation in the cost by the State and local interests.

Although the federal policy on such participation has not yet been established by Congress, the Statutes of the State of Connecticut anticipate this type of project and under Sections N209 and N207 establish a basis of cooperation and participation by both this Commission and the Town Flood and Erosion Control Board. When federal policy is finally established it should require only minor changes if any in the Statutes.

At the present time there are no funds directly applicable for State participation in such projects. Your past experience should indicate that the State's attitude as expressed by both executive and legislative branches toward participation in improvement-protective projects has been progressive.

Very truly yours,

A handwritten signature in dark ink, appearing to read "John J. Curry".

John J. Curry
Chief Engineer

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